

A Data Analytics Study for Adverse Reactions of Blood Donors by Age, Gender, and Donation Type

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ABSTRACT

The blood donation process is usually very safe, and blood donors are comfortable during the blood donation procedure; however, blood donors occasionally experience various types of adverse reactions during or at the end of blood donation. Some of these reactions are very minor while blood donors sometimes experience serious reactions as well. This study aims to analyze the various types of adverse reactions experienced by the blood donors. The study conducts detailed analysis on a significant amount of real data collected through a blood organization in the southern part of the United States and provides the results regarding the frequency and types of adverse reactions based on multiple attributes such as age, gender, and donation type.

KEYWORDS

Adverse Reactions, Blood Donation, Data Analytics, Healthcare, Information Systems

INTRODUCTION

Blood cannot be produced artificially, so it is very crucial that voluntary donors are safe and feel comfortable when donating blood. Blood donation procedure is normally very safe and tolerable for blood donors, however, occasionally blood donors experience various types of adverse reaction during or at the end of the blood donation (Assarian et al., 2011). Blood organizations usually recruit donors all the time. Adverse reactions can affect the recruitment and retentions of blood donors negatively (Eder, Notari IV, & Dodd, 2012). Donor satisfaction is very important to retain donors and due to adverse reactions, donors may not want to revisit (Custer et al., 2012). The Appendix displays the summary of various adverse events or symptoms experienced by blood donors for blood donation (Working Group, 2014).

This study considers some of the major reactions experienced by the blood donors frequently are briefly explained below:

- **Allergic:** Local allergy is the red or irritated skin at the venipuncture site that may cause itching and redness, whereas, generalized allergic reaction (anaphylactic reaction) usually starts soon after

DOI: 10.4018/IJBIR.20210101.0a4

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the procedure is begun and may progress rapidly to cardiac arrest, and may cause apprehension, anxiousness, flushing, swelling of eyes, lips or tongue, cyanosis, cough, wheezing, dyspnea, chest tightness, cramps, nausea, vomiting, diarrhea, tachycardia, hypotension, and altered mentation (Working Group, 2014).

- **Arterial Puncture:** Arterial puncture is a puncture of the brachial artery or of one of its branches by the needle used for bleeding the donor, collected blood can appear as lighter red color than usual, the needle and tubing may appear to pulsate, the blood bag fills quickly, and blood donor may experience weak pain in the elbow region (Working Group, 2014).
- **Flushing:** This is the facial flushing during blood donation.
- **Hematoma:** A hematoma reaction is the accumulation of blood in the tissues outside the vessels usually caused by blood flowing out of damaged vessels and accumulating in the soft tissues, which have major symptoms like bruising, discoloration, swelling and local pain (Working Group, 2014).
- **Nerve Trauma:** This is the injury or irritation of a nerve, may cause pain, tingling, burning sensations in hand, wrist, or shoulder area (Working Group, 2014).
- **Phlebitis:** This is the redness, swelling, and tenderness extend along the course of the vein (Working Group, 2014).
- **Return Line Infiltration:** This happens when intravenous solute (saline solution) enters the extravascular tissues during volume replacement (generally only applicable to double red cell procedures) and may cause swelling of the tissues at the venipuncture site (Working Group, 2014).
- **Tetany:** This can happen when overly stimulated nerves cause involuntary muscle cramps and contractions, and may cause vomiting, convulsions, serious pain, seizures, and heart dysfunction (Schaefer, 2017).
- **Transported:** This is the case when a blood donor is transported to a hospital or doctor's office for medical attention when the donor experience certain condition during or after the blood donation that requires medical attention. The number of cases found throughout this study was very minimal.
- **Vasovagal Reaction:** Vasovagal reaction is a general feeling of discomfort and weakness with anxiety, dizziness and nausea, which may progress to loss of consciousness, and considered as the most common acute complication related to blood donation that may create symptoms like discomfort, weakness, anxiety, light-headedness/dizziness, nausea, chills, sweating, vomiting, pallor, hyperventilation, rapid or a slow pulse (Working Group, 2014).
- **Other:** This includes all other types of reactions that are not very common and do not fall under the defined reaction classes or categories but have some effect.
- **No Apparent Reaction:** There are certain situations when blood donors experience some issues during or at the end of blood donation but the issues do not fall under any defined reactions class or category and do not have any effect on the health issue for the donors. These reactions were marked as "no apparent reaction" for this study and it appears that the number of reactions was not significant.

This study analyzes the major types of adverse reactions experienced by the blood donors during or at the end of the blood donation in terms of number and percent of total donations. It also analyzes the reactions by age. Reactions for both for minors (16 and 17 years old) and adults (18 years and older) are analyzed. The study shows the analysis of adverse reactions in terms of gender and donation type as well. Whole blood and automated blood donation types are analyzed for this study. Whole blood donation is the most flexible type of blood donation, can be transfused in its original form, or used to help multiple people when separated into its specific components of red cells, plasma and platelets, and the process takes about an hour (American Red Cross, 2019). Automated donation includes double red cells, platelets, and plasma donations. Double red cell donation allows a donor to give twice the amount of red cells given in a whole blood donation, and are the most-used blood

component for surgery, trauma and treatment of blood disorders; platelets are a component of the blood that help control bleeding, are often used to help patients with cancer, and an automated platelet donation is equal to platelets derived from six whole blood donations; plasma (the liquid portion of blood) transports red blood cells, white blood cells and platelets, and frequently given to burn and trauma patients to replace fluid loss (Blood Center, 2019). The comprehensive analysis in this study shows the relationship among the attributes like age, gender, and donation type with adverse reactions.

LITERATURE REVIEW

There are many studies have been conducted regarding the adverse reactions in blood donors in different parts of the world. For example, Sultan et al. (2016) conducted a study in Pakistan for allogenic blood donors and the study revealed that overall 1.3% of the donors experienced some kind of adverse reactions. Another study showed that 2.5% of blood donors in India experienced adverse reactions (Agnihotri, Marwaha, & Sharma, 2012). A study conducted in Bangalore, India found 2.04% adverse reactions experienced by the whole blood donors (Abhishekh, Mayadevi, & Usha, 2013). A Study conducted in Bangladesh found 4.9% adverse reactions experienced predominantly by male blood donors (Mahbub-ul-Alam et al., 2007). Crocco and D'Elia (2007) found 1.2% adverse reactions experienced by the blood donors in Italy. A Japanese study (Inaba et al.) found 2.8% adverse reactions in blood donors and a study conducted in Germany found 0.63% adverse reactions for elderly (66-71 years old donors) blood donors (Zeiler et al., 2011).

MATERIALS AND METHODS

This study collected data through a well-known blood organization in the United States. The blood organization organized campaigns in the southern part of the United States during the year 2018 and collected data during the blood collection. The campaign was conducted throughout 2018 starting from the month of January until the end of October. Communications were sent by direct mail, email, and sms (text messages) to both potential (possible new) and previous donors. The blood donation organization has many centers in the region where any donor can walk-in during the regular hours and come with an appointment made in advance as well. In addition, the organization frequently collects blood in mobile vans and buses. Data were collected about the blood donation and donors including gender, age, donation type or what kind of donation, etc. The demographics of the donors were also collected by the blood organizations but not used in this study to keep the confidentiality of the donors. Data collected were then analyzed based on certain criteria. A Microsoft SQL Server Database Management System was used to store the collected data. SQL Queries and Microsoft Excel were used to analyze the data. The data analysis results are presented and explained next in "Data Analysis and Results" Section.

DATA ANALYSIS AND RESULTS

This section provides the detail data analysis results.

Figure 1 displays the total number of blood collection versus the total number of reactions reported. As it can be seen that total 622,154 data about blood donations were collected and out of those total 12,449 number of adverse reactions experienced by blood donors which is 2% of the total blood donations. So, according to this study about 2% blood donors experienced some kind of adverse reactions.

Figure 2 displays the total blood donations by gender. As the figure shows, 275,770 (44.3%) blood donors were female and 346,384 (55.7%) were male.

Figure 1. Number of total blood donations vs. Reactions

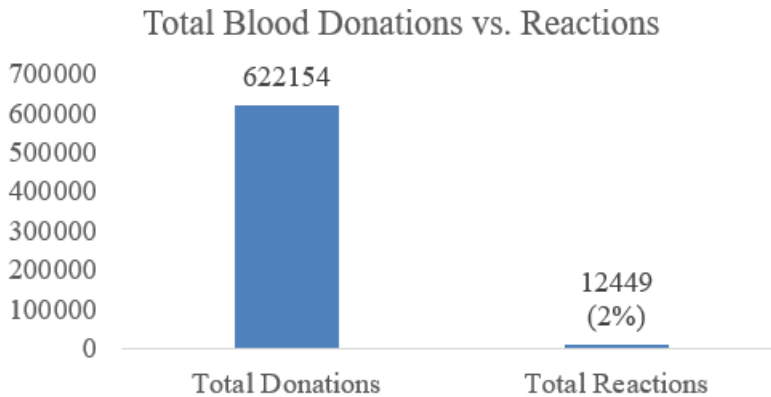


Figure 2. Number of blood donations by gender

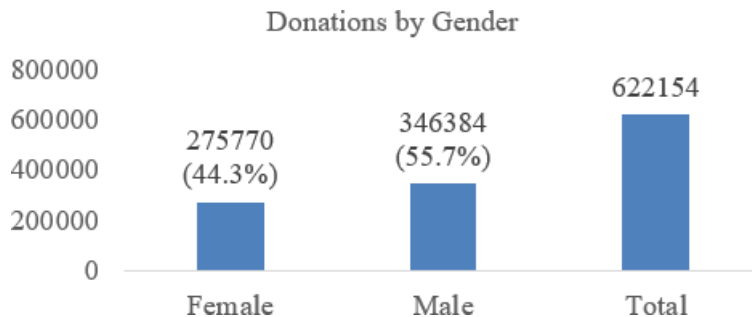


Figure 3 displays the number and percentage of reactions experienced by gender. It shows that overall 2.66% of female experienced adverse reactions which is little more than that experienced by male 1.5%.

Figure 4 displays the blood donations by age. This study aims to find the adverse reactions both on minors (16 and 17 years old) and adults. The minimum age to donate blood was set by the blood organization was 16. Even though 18 years old donors are considered adults, however, this study shows the results for 18 years old separately like 16 and 17 years as they are very close to minors and the study tries to see if 18 years old donors still have the similar reactions like 16 and 17 years old. As it can be seen that 3.7% (22,841) blood donations were from 16 years old donors, 5.7% (35,424) donations were from 17 years old donors, 4.3% (26,495) donations were from 18 years old donors, and 86.4% (537,394) donations were from donors of all other ages.

Figure 5 displays the donations versus the number and percent of adverse reactions by age. The graph cannot display the reactions as the numbers are comparatively low compared to the donations, but the tables underneath shows the details. As it can be seen that 3.8% of 16 years old donors had adverse reactions, 4.9% of 17 years old donors had adverse reactions, 5.5% of 18 years old had adverse reactions, and 1.6% of all other age donors had adverse reactions.

Figure 6 displays the blood donations by donation type. The total number of Whole Blood donations was 523,665 which is 84.2% of total blood donations, and total number of Automated donations was 98,489 which is 15.8% of total blood donations.

Figure 7 displays the number and percentage of adverse reactions by donation type. It shows that 1.7% (9,134 reactions out of 523,665 donations) whole blood donors experienced adverse reactions

Figure 3. Number and percentage of adverse reactions by gender

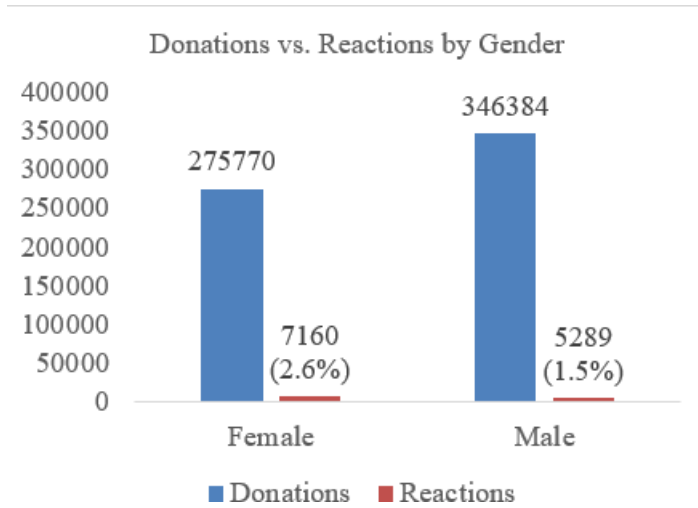
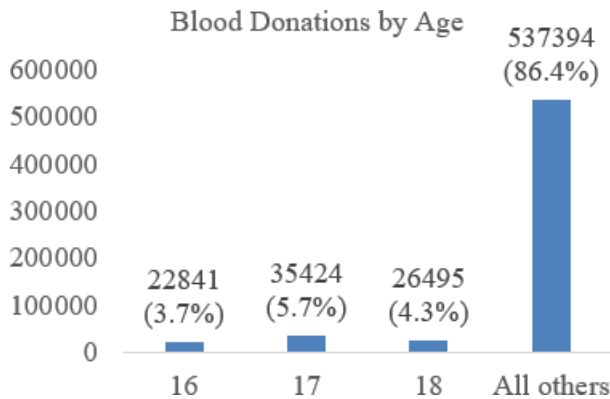


Figure 4. Blood donations by age



whereas 3.4% (3,315 reactions out of 98,489 donations automated donors experienced adverse reactions.

Figures 8 and 9 display the number of percentage of reactions compared to total number of adverse reactions respectively by major reaction classes or types. It can be seen that out of total 12,449 adverse reactions, vasovagal reaction has the highest percentage of 60.15% (7,488 reactions) followed by hematoma with 27.2% (3,386 reactions), then by other reactions which included several other types of reactions (that are not listed as major reaction class/type) with 6.67% (842 reactions), and then by return life infiltration with 4.57% (569 reactions). All other major reactions classes experienced by the blood donors are not very significant.

Figures 10 and 11 display the number and percentage of adverse reactions for major reaction class by gender. It can be seen that among the blood donors who experienced adverse reactions, female donors (70.25%) experienced little more vasovagal reactions than male donors (46.47%), whereas, male donors experienced little more hematoma (35.49% male versus 21.08% female) and return life infiltration (8.75% male versus 1.75% female) reactions.

Figure 5. Blood donations vs. Reactions by age

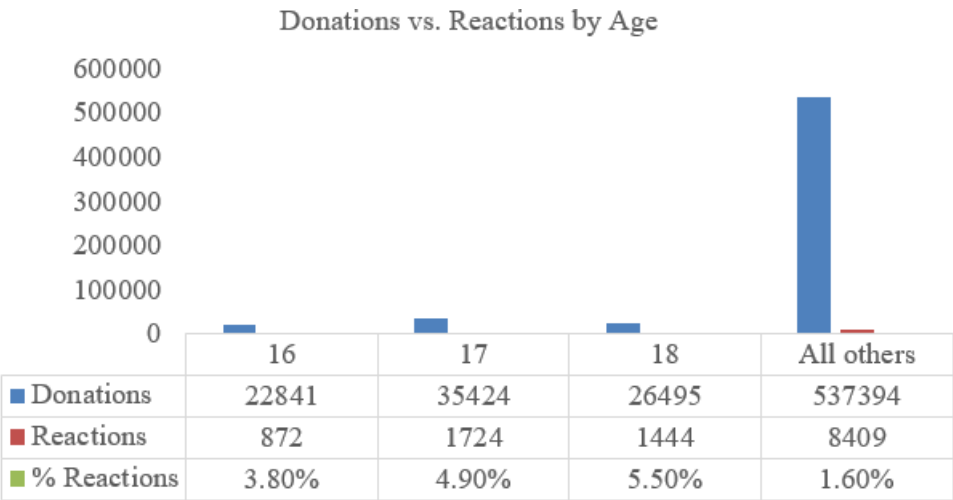


Figure 6. Blood donations by donation type

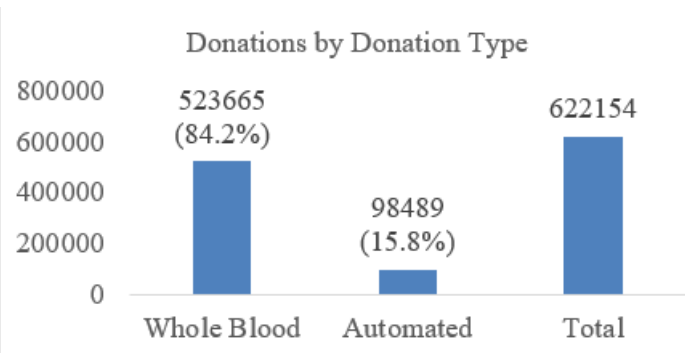


Figure 7. Blood donations vs. Reactions by donation type

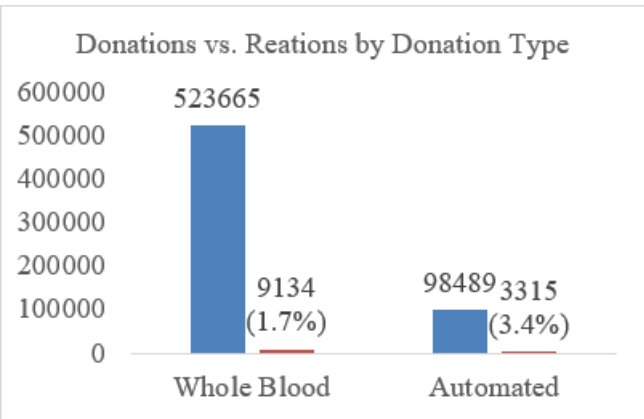


Figure 8. Number of reactions by major reaction class

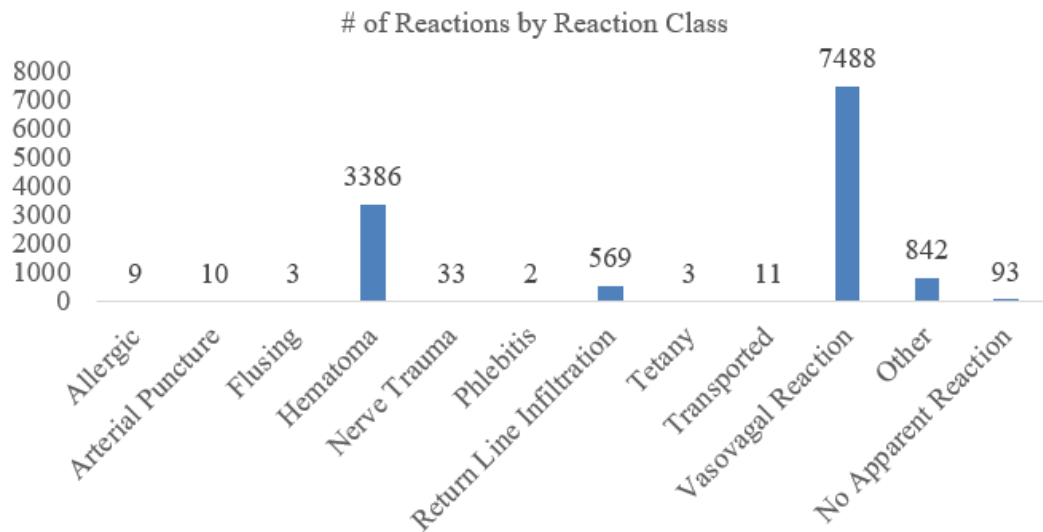


Figure 9. Percent of reactions by major reaction class

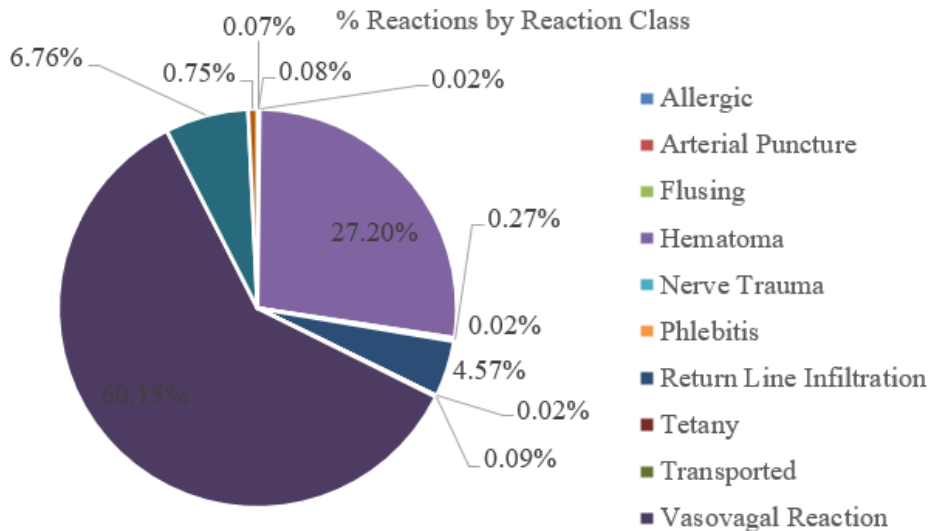


Table 1 displays the number of reactions for reaction class by age. For both minors and adults, vasovagal reaction class was experienced the highest followed by hematoma and then by return life infiltration.

Table 2 displays the number and percent of adverse reactions class by donation type. It can be seen that hematoma reactions are higher for automated donation (48.63%) compared to whole blood donations ((19.42%). Return life infiltration reactions are also much higher in percentage for automated donation (16.17%) compared to whole blood donation (0.36%). Other (not listed under major reaction class) reactions are higher as well for automated donation (12.28%) than whole blood

Figure 10. Number of major reaction class by gender

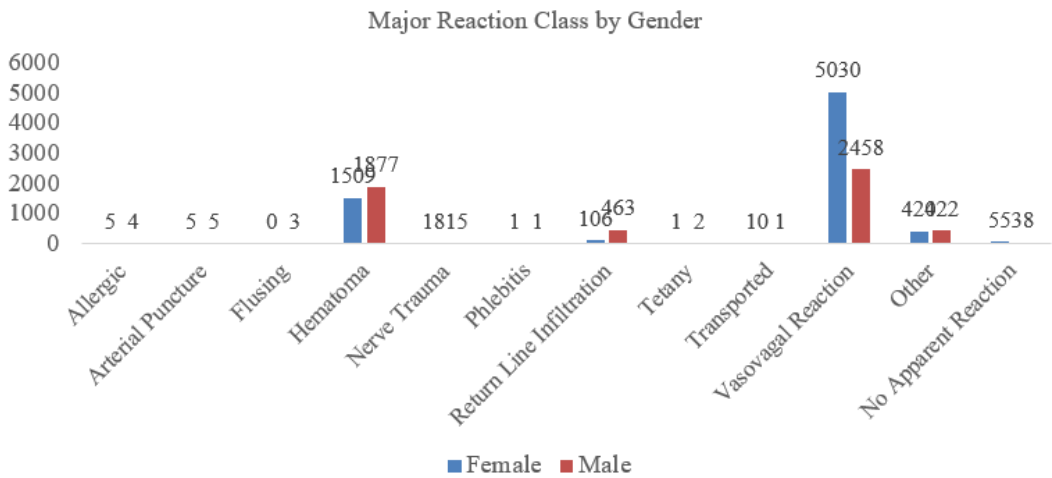
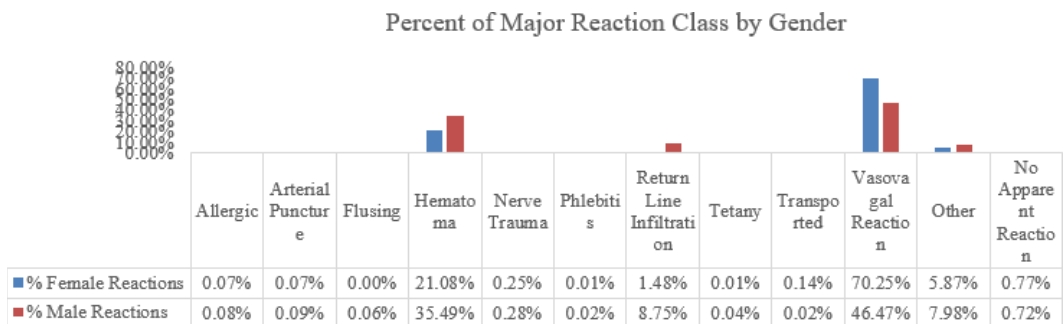


Figure 11. Percent of major reaction class by gender



donation (4.76%). However, vasovagal reactions are much higher for whole blood donation (73.94%) compared to automated donation (22.14%). All other classes of major reactions do not have much significant difference between automated and whole blood donations.

Table 3 displays the number of blood donations by gender, age, and donation type. Among the minors, it shows that 17 years old female donors had the highest number and it was for whole blood donations.

Table 4 displays the reactions by gender and age. It shows that among the 16, 17, and 18 years old donors, 18 years old female donors had experienced highest adverse reactions which is 7.3%, followed by 17 years old female donors which is 6.7%. It also can be seen that minor aged donors had significantly higher reactions compared to all other age adult donors.

Table 5 displays the reactions by donation type and age. It shows that among the 16, 17, and 18 years old donors, 18 years old donors experienced highest adverse reactions both for automated and whole blood donations which are 7.5% and 5.1% respectively. Also, among the minors (16 and 17 years old donor), 17 years old donors experienced highest number of reactions. It also can be seen that minor aged donors experienced significantly higher adverse reactions for both automated and whole blood donations compared to the average reactions for all other age adult donors except 18 years old donors.

Table 1. Reaction class (number of reactions) by age

Reaction Class	Age			
	16 Years	17 Years	18 Years	All Others
Allergic	1	1	1	6
Arterial Puncture	0	1	0	9
Flushing	0	0	0	3
Hematoma	106	236	267	2777
Nerve Trauma	0	2	2	29
Phlebitis	0	0	0	2
Return Line Infiltration	11	25	34	499
Tetany	0	1	0	2
Transported	0	1	0	10
Vasovagal Reaction	734	1387	1070	4297
Other	18	58	59	707
No Apparent Reaction	2	12	11	68
Total	872	1724	1444	8409

Table 2. Reaction class (number and percent of reactions) by donation type

Reaction Class	Donation Type			
	Automated		Whole Blood	
	# of Reactions	% Reactions	# of Reactions	% Reactions
Allergic	3	0.09%	6	0.07%
Arterial Puncture	0	0.00%	10	0.11%
Flushing	3	0.09%	0	0.00%
Hematoma	1612	48.63%	1774	19.42%
Nerve Trauma	10	0.30%	23	0.25%
Phlebitis	0	0.00%	2	0.02%
Return Line Infiltration	536	16.17%	33	0.36%
Tetany	0	0.00%	3	0.03%
Transported	0	0.00%	11	0.12%
Vasovagal Reaction	734	22.14%	6754	73.94%
Other	407	12.28%	435	4.76%
No Apparent Reaction	10	0.30%	83	0.91%

Table 3. Number of blood donations by gender, age, and donation type

Gender	16 Years		17 Years		18 Years		All Others	
	Automated	Whole Blood	Automated	Whole Blood	Automated	Whole Blood	Automated	Whole Blood
Female	305	12371	526	16184	388	11319	17521	217156
Male	1705	8460	4152	14562	3256	11532	70636	232081

Table 4. Reactions by gender and age

Donation Type	16 Years			17 Years		
	Donations	Reactions	% Reactions	Donations	Reactions	% Reactions
Female	12676	615	4.9%	16710	1120	6.7%
Male	10165	257	2.5%	18714	604	3.2%
Donation Type	18 Years			All others		
	Donations	Reactions	% Reactions	Donations	Reactions	% Reactions
Female	11707	854	7.3%	234677	4571	1.9%
Male	14788	590	4.0%	302717	3838	1.3%

DISCUSSION

This study was conducted in the southern part of the United States. The study collected data about 622,154 blood donations and detected 12,449 adverse reactions for whole blood and automated donations for all different ages of donors. So, the overall adverse reactions found in 2% of blood donors. Male donors were more than female donors with 55.7% compare to 44.3%, however, overall female donors experienced adverse reactions more than those of male donors with 2.66% compared to 1.5%. A significant number of donors were minors (16 and 17 years old). Total 58,265 donations were from minor donors out of 622,154 donations which is about 9.37%, out of which 3.7% were from 16 years old donors and 5.7% were from 17 years old donors. Also, 4.3% donations were from 18 years old donors. Minor aged blood donors also experienced higher adverse reactions than those of adult donors. 3.8% of 16 years old donors experienced some kind of adverse reactions, and 4.9% of 17 years old donors experienced adverse reactions which are higher than overall 2% adverse reactions

Table 5. Reactions by donation type and age

Donation Type	16 Years			17 Years		
	Donations	Reactions	% of Reactions	Donations	Reactions	% of Reactions
Whole Blood	20831	794	3.8%	30746	1505	4.9%
Automated	2010	78	3.9%	4678	219	4.7%
Donation Type	18 Years			All others		
	Donations	Reactions	% of Reactions	Donations	Reactions	% of Reactions
Whole Blood	22851	1170	5.1%	449237	5665	1.3%
Automated	3644	274	7.5%	88157	2744	3.1%

experienced by all donors and also much higher than average 1.6% adverse reactions experienced by donors more than 18 years old. 18 years old donors also experienced higher adverse reactions as well which is 5.5%.

Whole blood donations outweighed automated donations with 84.2% compared to 15.8%. However, automated donations had more adverse reactions than those of whole blood donations with 3.4% compared to 1.7%.

Major adverse reactions were analyzed and the study found that vasovagal reaction had been experienced the highest by the blood donors with 60.15% followed by hematoma with 27.2%. Next major adverse reactions experienced by the blood donors was return life infiltration with 4.57%. The study also found that female donors experienced vasovagal reactions more than those of male donors with 70.25% compared to 46.47%, whereas male donors experienced hematoma more than those of female donors with 35.49% compared to 21.08%. Male donors also experienced return life infiltration more than those of female donors with 8.75% compared to 1.75%. In regards to age of the blood donors, vasovagal reaction class was experienced the highest followed by hematoma and then by return life infiltration for both minors and adults.

The study also showed that hematoma reactions were higher for automated donations with 48.63% compared to whole blood donations with 19.42%. Return life infiltration reactions were also higher for automated donations with 16.17% compared to whole blood donations with 0.36%. However, vasovagal reactions were much higher for whole blood donations with 73.94% compared to automated donations with 22.14%.

Considering the combination of age and gender, the study found that 18 years old female donors had experienced adverse reactions the highest which is 7.3%, followed by 17 years old female donors which is 6.7%.

Considering the combination of age and donation type, the study found that among the 16, 17, and 18 years old donors, 18 years old donors experienced highest reactions both for automated and whole blood donations which are 7.5% and 5.1% respectively. Also, among the minors (16 and 17 years old donor), 17 years old donors experienced highest number of adverse reactions both for whole blood and automated donations. It also showed that minor aged donors had significantly higher adverse reactions for both automated and whole blood donations compared to the average reactions for all other age adult donors except 18 years old donors.

The results found in the study will provide the blood organizations a very good picture of adverse reactions experienced by the blood donors during or at the end of blood donation. Blood organizations should be able take some precautions knowing some facts found in the study about what type of blood donors in terms of age such as minors and adults experience what types of adverse reactions such as vasovagal, hematoma, etc., and during what type of donations such as whole blood or automated. The study will provide a significant value for the blood organizations as well as blood donors by knowing some possible adverse reactions in advance.

RECOMMENDATION

Based on the results found in the study, the authors recommend certain precautions both for the blood organizations and blood donors as listed below:

- Female blood donors should be given more attention during the blood donation as they experience higher adverse reactions than male donors.
- Minor blood donors (16 and 17 years old) as well as 18 years old donors should be given more attention as well during the blood donation as they experience higher adverse reactions than adult blood donors.
- Automated donations had more adverse reactions than whole blood donations, so more precautions should be taken during automated donations.

- There should be sufficient after adverse reactions care available, especially for highly experienced reactions such as vasovagal and hematoma.

LIMITATIONS OF THE STUDY

The study was conducted in a specific region (southern part of the United States) that can have some biasness on ethnicity, age, etc. for donors. Also, the time of the campaigns and donations can have some effect on the turn out rate of the donors. But as it can be seen from the results of analysis described earlier, a significant number of donors actually came and donated blood and amount of data seems to be more than sufficient. So, the analysis surely provides a clear picture on the adverse reactions in terms of multiple attributes like age, gender, and donation type. This study will also serve as a suitable source to further research and advanced study in the field.

CONCLUSION

This paper presents the study of adverse reactions in blood donors. The study was conducted for the blood donors in the southern part of the United States and a significant amount of data were collected through a blood donation organization. The study conducted detail data analytics unlike to other relevant studies (Miah et al. 2017; Miah et al. 2019a and Miah et al. 2019b) on the data to analyze the major types of adverse reactions frequency in blood donors. The study also presented the data analysis results on adverse reactions in regards to multiple attributes of blood donors including age, gender, and donation type. The authors hope that the results of the data analysis will provide a very good indication on the adverse reactions experienced by the blood donors during or at the end of the blood donation, as well as provide attentions for blood organizations to take precautions during the blood donation process. The study should also provide a good source for further research and advanced study in the field. For instance, leading to this study, a further study is outlined for design more formal analytics solution artifact that would be ensuring decision makers' value within organizational context guiding through the relevant studies (Miah 2009 and 2010; Miah and Gammack, 2010). Design aspects on how an innovative analytics modeling as decision support artifact (Miah and Gammack, 2014; Geremo et al. 2015; Miah, 2008) can be studied within organizational or community context and it would be the key objective to focus for more contextualization. The analytics platform can be viewed as an end-user's decision support and IoT oriented platform (de Vass et al. 2018; Ali et al. 2018) for different decision makers' requirements.

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APPENDIX

Table 6.

A. Local Symptoms	
A1 Blood outside vessel	• Hematoma • Arterial puncture • <i>Delayed bleeding</i>
A2 Arm pain	• Nerve injury/irritation <i>duration < 12 months</i> <i>duration > 12 months</i> • Other arm pain
A3 Localized infection/inflammation of vein or soft tissues	• Superficial thrombophlebitis • Cellulitis
A4 Other major blood vessel injury	• Deep Venous Thrombosis (DVT) • Arteriovenous fistula • Compartment syndrome • Brachial artery pseudoaneurysm
B. Generalized symptoms – Vasovagal Reactions	
	• Vasovagal Reaction, no loss of consciousness (LOC) • Vasovagal Reaction, loss of consciousness <i>< 60 seconds, no complications</i> <i>≥ 60 seconds, and/or convulsions or incontinence</i> • <i>With injury</i> • <i>Without injury</i> • <i>On collection site</i> • <i>Off collection site</i>
C. Related to apheresis	
	• Citrate reactions • Hemolysis • Air embolism • <i>Infiltration</i>
D. Allergic reactions	
	• Local allergic reaction • Generalized (anaphylactic) reaction
E. Other serious complications	
	• Acute cardiac symptoms (other than myocardial infarction or cardiac arrest). • Myocardial infarction • Cardiac arrest • Transient Ischemic Attack (TIA) • Cerebrovascular accident • Death
F. Other	
For A-F, optional separate reporting of reactions classified as serious according to standard criteria (life-threatening or leading to hospitalization, incapacity, chronic morbidity or death).	

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